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(54) **VEHICLE ELECTRICAL SYSTEM FAULT
DETECTION**

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(58) **Field of Classification Search**

USPC 361/93.1
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,804,944 A * 9/1998 Alberkrack et al. 320/163
6,034,581 A * 3/2000 DiMarco et al. 335/16
6,037,676 A * 3/2000 Foree 307/10.7
6,404,163 B1 6/2002 Kapsokavathis et al.

6,809,501 B2 10/2004 Kapsokavathis et al.
7,009,365 B1 3/2006 Namuduri et al.
7,122,993 B2 10/2006 Bauerle et al.
7,460,344 B2 * 12/2008 Hastings et al. 361/42
8,526,145 B2 * 9/2013 Fanzutti et al. 361/42
2005/0219779 A1 * 10/2005 Kim 361/56
2010/0213948 A1 8/2010 Bauer et al.
2011/0246205 A1 * 10/2011 Lin et al. 704/500

FOREIGN PATENT DOCUMENTS

CN 1087585 C 7/2002
CN 101718842 A 6/2010
WO 9603018 A1 2/1996

OTHER PUBLICATIONS

KR-2012-0033191, Transient current monitoring device and method
for dc voltage source system; Abstract, specification, drawings.*

KR-101145497, KR20120033191; Transient current monitoring
device and method for DC voltage source system; abstract, speci-
fication.*

State Intellectual Property Office of the People's Republic of China,
Office Action in Chinese Patent Application No. 201310181093.8
mailed May 6, 2015.

* cited by examiner

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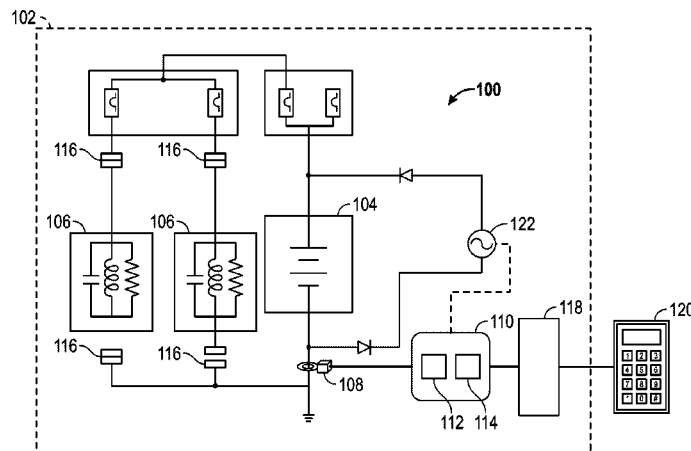
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ABSTRACT

Methods and systems are provided for sensing electrical
faults. The system includes a current sensor disposed between
a battery and at least one electrical load. The current sensor is
capable of sensing electrical current flowing from the battery
to the load at a sensitivity sufficient to detect a current tran-
sient. The system also includes a controller in communication
with the current sensor. The controller is capable of compar-
ing the sensed current transient to a predetermined current
transient for the load and signaling a fault when the sensed
current transient and the predetermined current transient vary
by a predetermined amount.

15 Claims, 3 Drawing Sheets



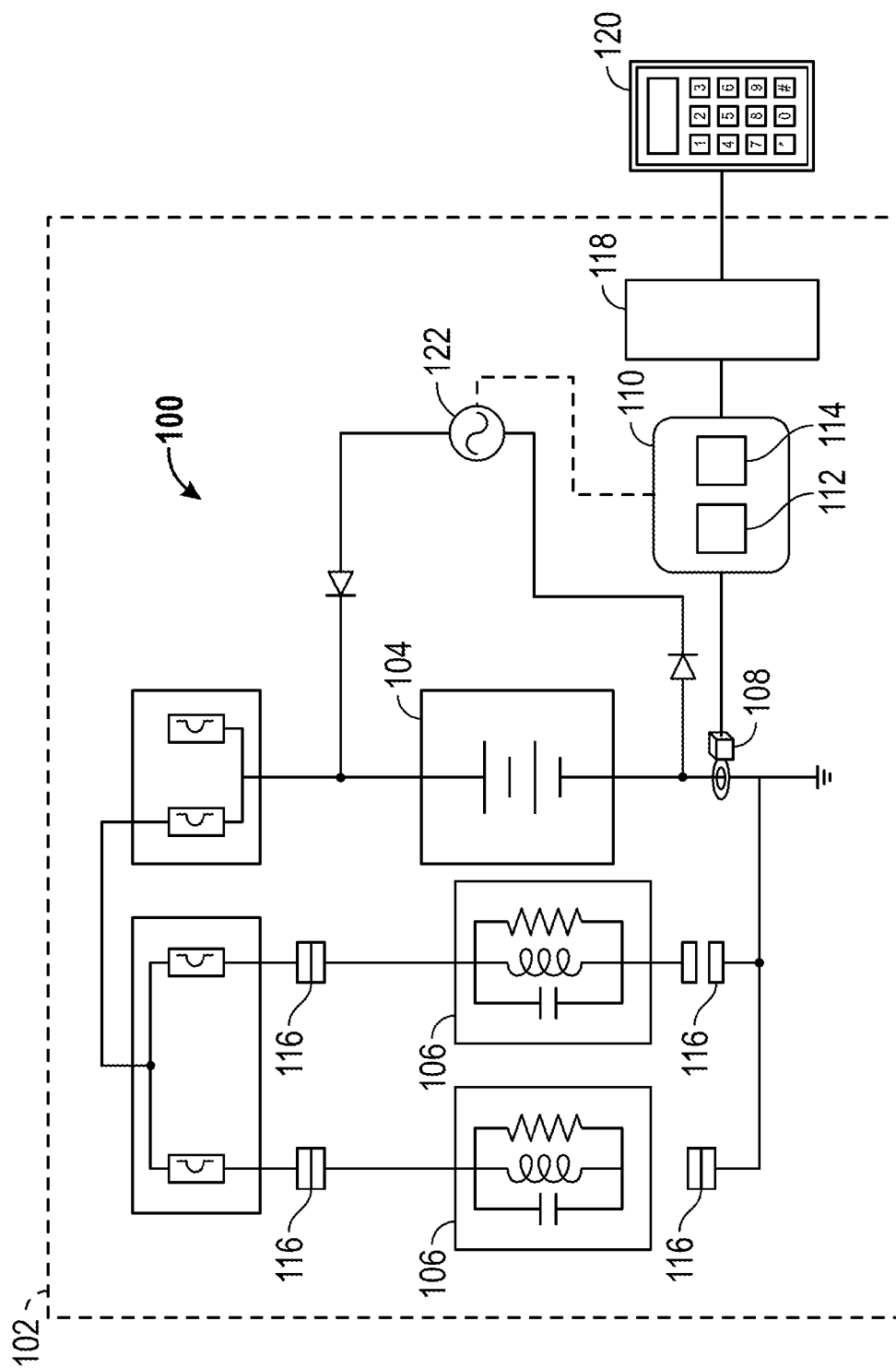


FIG. 1

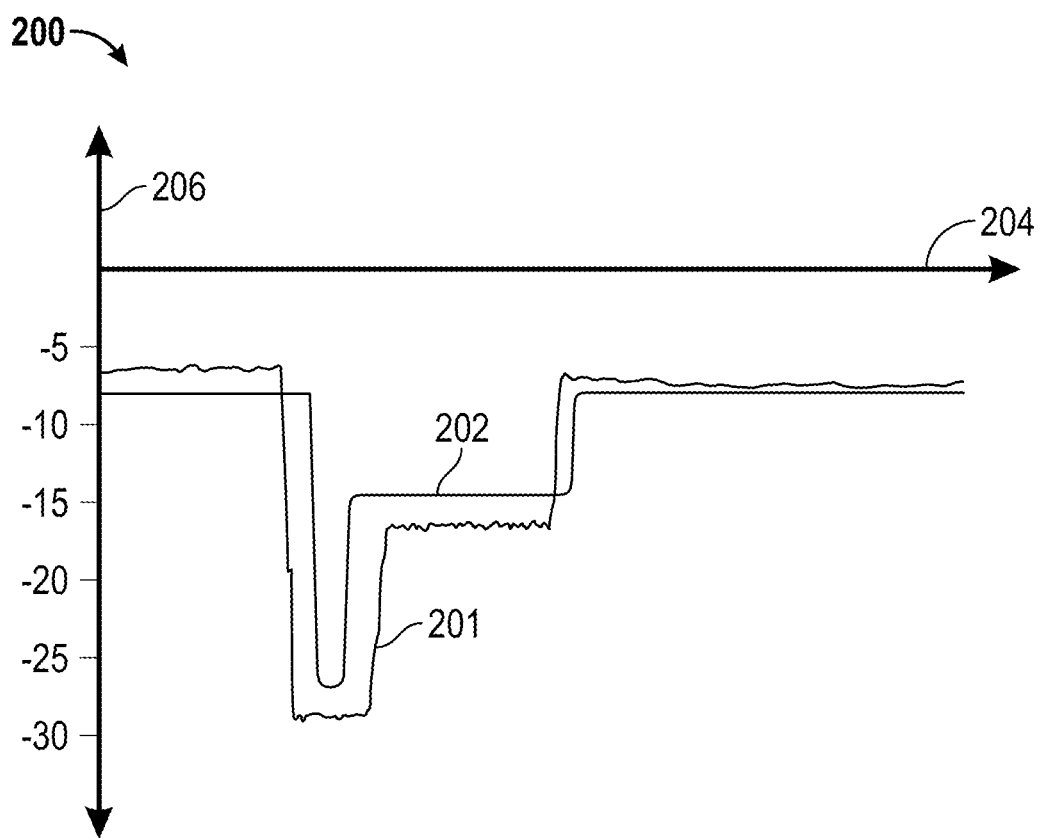


FIG. 2

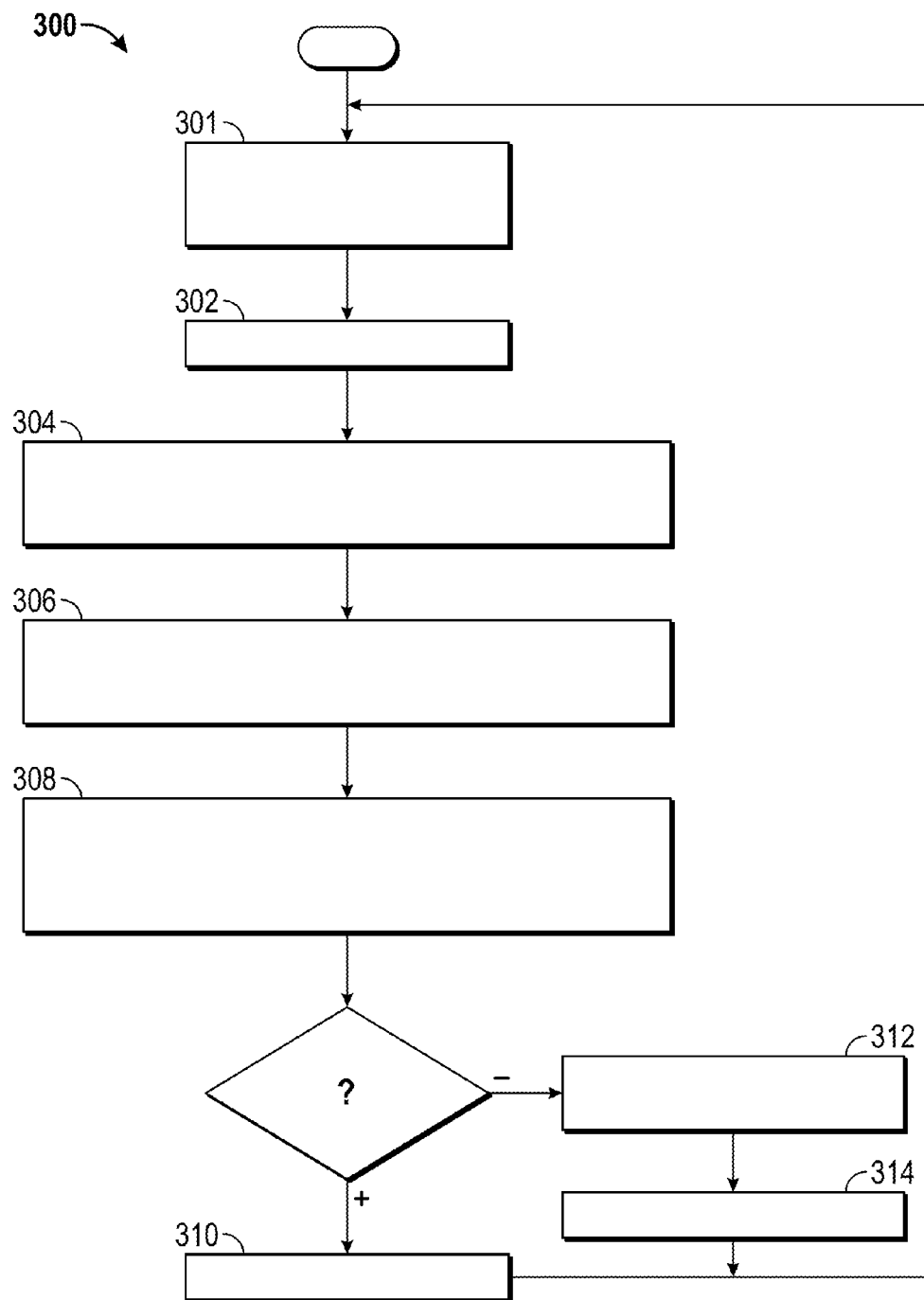


FIG. 3

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VEHICLE ELECTRICAL SYSTEM FAULT DETECTION

TECHNICAL FIELD

The technical field generally relates to a system and method for detecting electrical faults and more particularly relates to a system and method for detecting electrical faults in a vehicle.

BACKGROUND

Current electrical fault detection techniques for motor vehicles are typically rudimentary. For instance, during assembly or maintenance of a vehicle, a technician may simply activate electrical loads, such as headlamps, turn signals, a motor starter, etc., and visually verify that they operate. Unfortunately, such basic testing does little to reveal future problems, such as loose electrical connectors, strained electrical wiring, or loads that are nearing the end of their life.

Accordingly, it is desirable to provide systems and methods for determining hidden electrical problems in vehicle prior to the load simply not responding. Furthermore, other desirable features and characteristics of the present invention will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and the foregoing technical field and background.

SUMMARY

A system is provided for detecting electrical faults. In one embodiment, the system includes a current sensor disposed between a battery and at least one electrical load. The current sensor is capable of sensing electrical current flowing from the battery to the load at a sensitivity sufficient to detect a current transient. The system also includes a controller in communication with the current sensor. The controller is capable of comparing the sensed current transient to a predetermined current transient for the load and signaling a fault when the sensed current transient and the predetermined current transient vary by a predetermined amount.

A method is provided for detecting electrical faults. In one embodiment, the method includes activating a load. An electrical current is sensed flowing from a battery to the load at sensitivity sufficient to detect a current transient. The method further includes comparing the sensed current transient to a predetermined current transient for the load. The method also includes signaling a fault when the sensed current transient and the predetermined current transient vary by a predetermined amount.

DESCRIPTION OF THE DRAWINGS

The exemplary embodiments will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and wherein:

FIG. 1 is block schematic diagram of an electrical fault detection system in accordance with an embodiment;

FIG. 2 is a graph showing a sensed current transient for a load and a predetermined current transient of the load in accordance with an embodiment; and

FIG. 3 is a flowchart showing a method of detecting electrical faults in accordance with an embodiment.

DETAILED DESCRIPTION

The following detailed description is merely exemplary in nature and is not intended to limit the application and uses.

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Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description.

Referring to FIG. 1, an electrical fault detection system **100** is shown and/or described herein. The system **100** of the illustrated embodiment is described for use in a vehicle **102**. Specifically, the system **100** of the illustrated embodiment may be used in an automobile (not separately numbered). However, those skilled in the art appreciate that the system **100** may be used with other types of vehicles **100** or non-vehicle applications.

The vehicle **102** includes a battery **104** for supplying electrical energy. As is well known by those skilled in the art, the battery **104** may include one or more electrochemical cells (not shown) that convert stored chemical energy into electrical energy. In the illustrated embodiment, the battery **104** is rechargeable, i.e., a secondary battery. However, in other embodiments, the battery **104** may be a primary battery.

The vehicle **102** further includes at least one electrical load **106** electrically connectable to the battery **104** for using the electrical energy supplied by the battery **104**. In the illustrated embodiment, a plurality of loads **106** is shown. These loads **106** may include, but are certainly not limited to, a light, an electric starter, a radio, a sensor, and a display. However, those skilled in the art realize the vast variety of electrical loads **106** that may be implemented in the vehicle **102** or other loads **106** for non-vehicle applications. Furthermore, although multiple loads **106** may be utilized in the vehicle **102** and the system **100** described herein, the at least one electrical load **106** may be referred to simply as “the load **106**” for ease of readability.

The system **100** includes a current sensor **108** disposed between the battery **104** and the load **106**. The current sensor **108** senses electrical current flowing from the battery **104** to the load **106**. Specifically, the current sensor **108** senses electrical current to the load **106** at a sensitivity sufficient to detect a current transient. That is, the current sensor **108** is sensitive enough to detect the “inrush current” or “surge current” that occurs when the load **106** is activated.

The system **100** further includes a controller **110**. The controller **110** may comprise a microprocessor, a microcontroller, an application specific integrated circuit (“ASIC”), a digital signal processor (“DSP”), or any other suitable digital computational device. The controller **110** is in communication with the current sensor **108**. That is, the controller **110** is electrically connected to the current sensor **108** such that readings from the current sensor **108** may be received and processed by the controller **110**. More specifically, the controller **110** may include an analog-to-digital converter (“ADC”) **112** for converting an analog signal from the current sensor **108** to a digital signal, as well appreciated by those skilled in the art. The controller **110** may be a stand-alone device, or may be integrated with other suitable device, e.g., a multi-function microprocessor used to control numerous aspects of the vehicle **102**.

As with the current sensor **108**, the controller **110** also has a sensitivity sufficient to detect a current transient. For instance, a sample rate of the ADC **112** must be sufficient to detect the spike in current that occurs over a very short period of time. In one embodiment, the sample rate is at least 750 kHz. That is, the ADC **112** produces at least 750,000 samples per second from the signal provided by the current sensor **108**. In another embodiment, the sample rate is at least 1 MHz, or 1,000,000 samples per second. In yet another embodiment, the sample rate is between 3 and 5 MHz. Of course, the higher the sample rate, the more sensitive the

controller 110 is to detecting current transients. However, the ADC 112 need only have a sample rate sufficient to detect the current transient.

In the illustrated embodiment, the current sensor 108 and the controller 110 are sufficiently sensitive to detect a 0.01 ampere ("A") change in current. More specifically, the current sensor and the controller 110 of the illustrated embodiment are sufficiently sensitive to detect a one milliamper ("mA") change in current.

The controller 110 also includes a memory 114 for storing data. Those skilled in the art will realize a wide variety of suitable techniques and/or devices for implementing the memory 114, including, but certainly not limited to, random access memory ("RAM"), read-only memory ("ROM"), optical storage devices (e.g., compact discs), flash memory, and magnetic discs (e.g., hard drives, floppy discs).

At least part of the memory 114 stores at least one predetermined current transient for each load 106. For example, one predetermined current transient for a specific load 106 is data corresponding to an ideal current transient, (i.e., a "gold standard" current transient) for when that load 106 is activated. Other current transients for the load 106 may be data corresponding to a variety of non-ideal current transients for the load 106. For instance, one predetermined current transient for the load 106 may be data corresponding to a situation where a wire (not numbered) leading to the load has become loose, but not disconnected from a connector (not shown). Another predetermined current transient for the load may be data corresponding to a situation where the impedance of the load has increased.

The controller 110 is capable of comparing the sensed current transient to the ideal current transient for the load. By performing this comparison, the controller 110 can determine whether or not the sensed current transient is ideal or if a non-ideal (i.e., abnormal) condition occurs. The controller 110 is also capable of signaling a fault when the sensed current transient and the predetermined current transient vary by a predetermined amount. That is, the controller 110 may signal a fault if the predetermined current transient is non-ideal. Moreover, the controller 110 of the illustrated embodiment is capable of comparing the sensed current transient to other predetermined current transient, such that the exact reasons for the fault may be deduced, or at least estimated.

The system 100 may include one or more disconnect switches 116 electrically connected between the battery 104 and the load 106. The disconnect switches 116 may be configured to allow manual and/or automatic activation and deactivation of the load 106. For automatic control, at least one of the disconnect switches 116 may be in communication with the controller 110 such that the controller 110 can close or open switch 116.

The controller 110 may deactivate the load 106 in response to a fault being detected. For example, if the controller 110 determines that the sensed current transient is not ideal, the controller 110 may deactivate the load 106 by opening the switch 116 associated with the load 106.

With continuing reference to FIG. 1, FIG. 2 shows a graph 200 comparing the sensed current transient 201 to the ideal current transient 202 during the activation and deactivation of the load 106. The horizontal axis 204 represents time and the vertical axis 206 represents current draw from the battery 104. As can be seen, in the illustrated graph 200, the time of sensed current transient 201 is longer than the time of the ideal current transient 202 and the amount of current draw of sensed current transient 201 is greater than the ideal current transient 202. This may represent a fault in the load 106 that is being measured or the wiring to the load 106. As such, a

fault would be signaled by the controller 110. Potentially, the load 106 may be disabled to prevent damage to the load 106. Of course, the comparison in FIG. 2 is only exemplary, and that other sensed and ideal current transient comparisons may appear different when represented graphically.

The system 100 of the illustrated embodiment further includes a connector 118 electrically connected to the controller 110. The connector 118 allows a remote control unit 120 to be electrically connected to the controller 110. The remote control unit 120 allows a user to interface with the controller 110. Specifically, in the illustrated embodiment, the user may operate the remote control unit 120 to begin testing one or more of the loads 106. During this testing process, the remote control unit 120 may direct a user to manually activate and/or deactivate the load 106. Once activated, the controller 110 receives the signal from the sensor 108 and determined whether or not to signal a fault, as described above.

The remote control unit 120 may be portable and disconnectable from the connector 118 (and thus disconnectable from the controller 110). However, in other embodiments, the remote control unit 120 may be permanently integrated into an electronic display (not shown) or other such control panel (not shown) of the vehicle 102.

The system 100, particularly when implemented in the vehicle 102, may include an alternator 122 for charging the battery 104. The alternator may be selectively connected to a motor (not shown) of the vehicle 102. Operation of the alternator 122 may be controlled by the controller 110. The controller 110 may control the alternator 122 to selectively charge the battery based, at least in part, on the current sensed by the current sensor 108. As such, the alternator 122 may be turned off to improve fuel economy of the vehicle 102.

A method 300 of detecting electrical faults has been described above with relation to the described system 100. However, the method 300 may be implemented in other systems not specifically described herein. The method 300, as shown in FIG. 3, may include the step 301 of directing a user to manually activate one of a plurality of loads. The method 300 includes the step 302 of activating a load. Once the load is activated, the method 300 continues with the step 304 of sensing electrical current flowing from a battery to the load at sensitivity sufficient to detect a current transient. The method 300 further includes the step 306 of comparing the sensed current transient to a predetermined current transient for the load. The method 300 may also include the step 308 of signaling a fault when the sensed current transient and the predetermined current transient vary by a predetermined amount. Furthermore, the method 300 may include the step 310 of disabling the load in response to the signaling of the fault. If no fault is detected the method 300 may include the step 312 of directing the user to disconnect the load and the step 314 of disconnecting the load.

While at least one exemplary embodiment has been presented in the foregoing detailed description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the disclosure in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing the exemplary embodiment or exemplary embodiments. It should be understood that various changes can be made in the function and arrangement of elements without departing from the scope of the disclosure as set forth in the appended claims and the legal equivalents thereof.

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What is claimed is:

1. A method for detecting electrical faults, comprising:
activating a load;
sensing electrical current flowing from a battery to the load
at sensitivity sufficient to detect a current transient;
comparing the sensed current transient to a predetermined
current transient for the load; and
signaling a fault when the sensed current transient and the
predetermined current transient vary by a predetermined
amount.
2. A method as set forth in claim 1 further comprising
disabling the load in response to the signaling of the fault.
3. A method as set forth in claim 1 wherein the sensitivity
is sufficient to detect a 0.01 ampere (A) change in current.
4. A method as set forth in claim 1 wherein the sensitivity
is sufficient to detect a one milliamper (mA) change in
current.
5. A method as set forth in claim 1 further comprising
directing a user to manually activate the load.
6. A method as set forth in claim 5 further comprising
directing the user to manually deactivate the load after the
electrical current flowing from the battery to the load has been
sensed.
7. An electrical fault detection system, comprising:
a current sensor configured to be disposed between a bat-
tery and at least one electrical load and further config-
ured to sense electrical current flowing from the battery
to the load at a sensitivity sufficient to detect a current
transient; and
a controller in communication with said current sensor for
comparing the sensed current transient to a predeter-
mined current transient for the load and signaling a fault
when the sensed current transient and the predetermined
current transient vary by a predetermined amount.
8. A system as set forth in claim 7, further comprising a
connector electrically connected to said controller for allow-
ing a remote control unit to be electrically connected to said

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controller, the remote control unit capable of directing a user
to manually activate and/or deactivate the load.

9. A system as set forth in claim 7 wherein the sensitivity is
sufficient to detect a 0.01 ampere (A) change in current.

10. A system as set forth in claim 7 wherein the sensitivity
is sufficient to detect a one milliamper (mA) change in
current.

11. A vehicle, comprising:

at least one electrical load;

a battery electrically connected to the at least one electrical
load for supplying electrical power to the at least one
electrical load;

a current sensor disposed between said battery and said at
least one electrical load for sensing electrical current
flowing from said battery to said at least one electrical
load at a sample rate sufficient to detect a current tran-
sient;

a controller in communication with said current sensor for
comparing the sensed current transient to a predeter-
mined current transient for said at least one electrical
load and producing a fault signal when the sensed cur-
rent transient and the predetermined current transient
vary by a predetermined amount.

12. A vehicle as set forth in claim 11, further comprising a
connector electrically connected to said controller for allow-
ing a remote control unit to be electrically connected to said
controller, the remote control unit capable of directing a user
to manually activate and/or deactivate said at least one elec-
trical load.

13. A vehicle as set forth in claim 11, further comprising a
generator electrically connected to said battery for charging
said battery.

14. A vehicle as set forth in claim 11 wherein the sensitivity
is sufficient to detect a 0.01 ampere (A) change in current.

15. A vehicle as set forth in claim 11 wherein the sensitivity
is sufficient to detect a one milliamper (mA) change in
current.

* * * * *